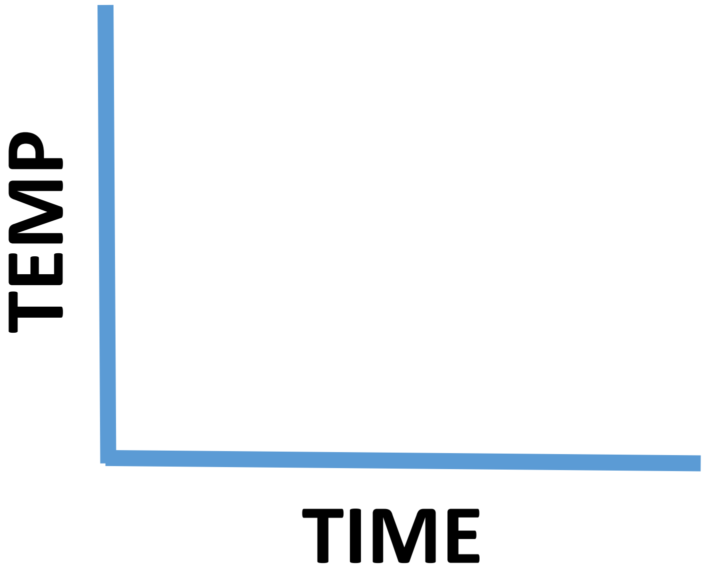
N37
Heating and Cooling Curves

Target: I can use heating and cooling curves to help calculate the energy changes during phase changes

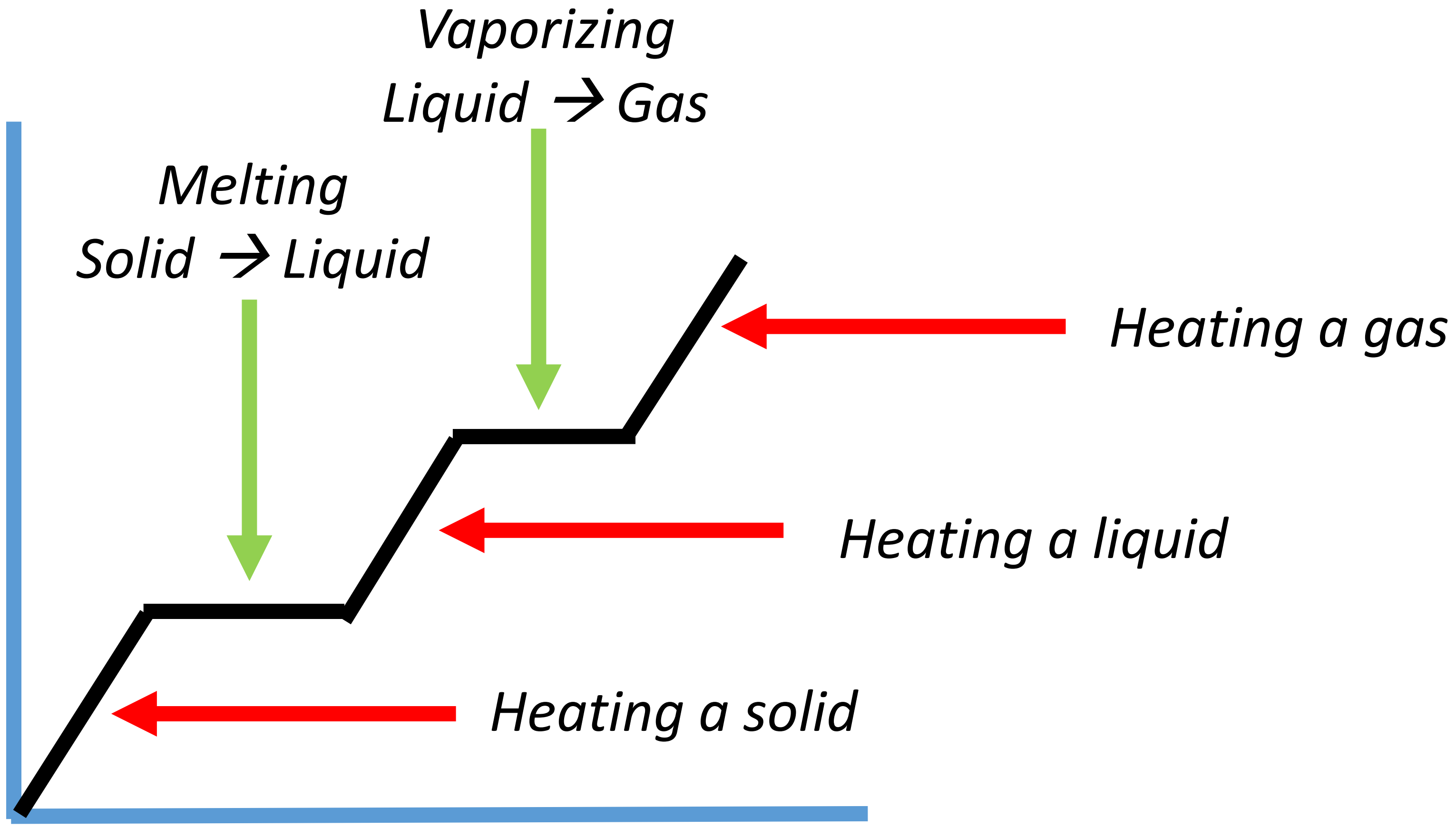
Link to YouTube Presentation: https://youtu.be/g2srRytHiX0

What do they show us?

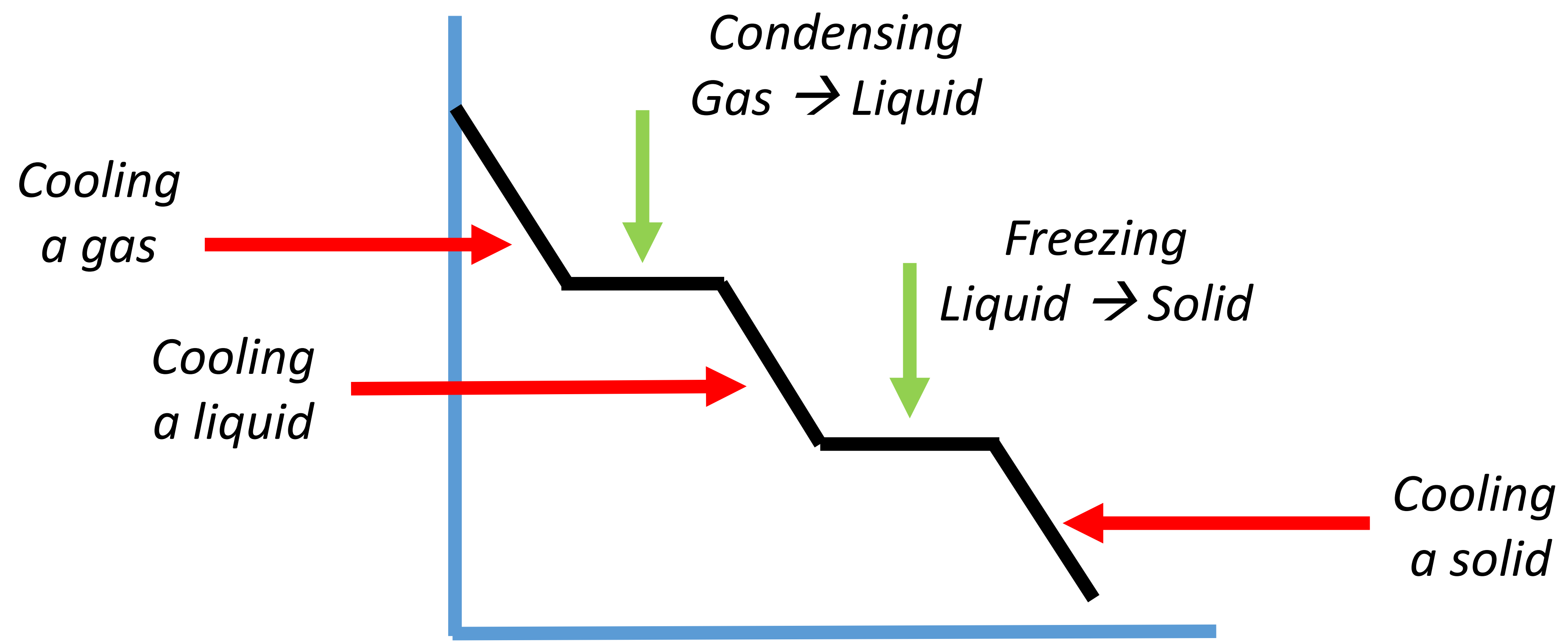
- Heating or cooling → *the sloped parts of graph*
- Phase changes → *the flat parts of graph*



Heating Curve



Cooling Curve



Why are some areas sloped and some flat?

Heating	Phase Changes

(Cooling would just be the opposite of these things!)

Why are some areas sloped and some flat?

Heating	Phase Changes
Issue: **SPEED**	Issue: **POSITION**
All the energy is going towards **SPEEDING UP** the molecules	All the energy is going towards **SPREADING OUT** the molecules
Results in a temperature change	Results in **NO** temperature change

(Cooling would just be the opposite of these things!)

How is our math changed by NO ΔT?

HEATING/COOLING

- $Q = mC\Delta T$
- $C = J/g°C$ → Has a temperature component.
- So…. Cant use it for phase changes

PHASE CHANGES

- $\Delta T = 0$ BUT $Q \neq 0$
- Get rid of ΔT, and replace C with something else
- **$Q = mL$**
- L = "Latent Heat" → J/g
  The energy required to phase change one gram of substance

Specific Heat and Latent Heat Labels

HEATING/COOLING

- C_{solid}
- C_{liquid}
- C_{gas}
- Always positive values

PHASE CHANGES

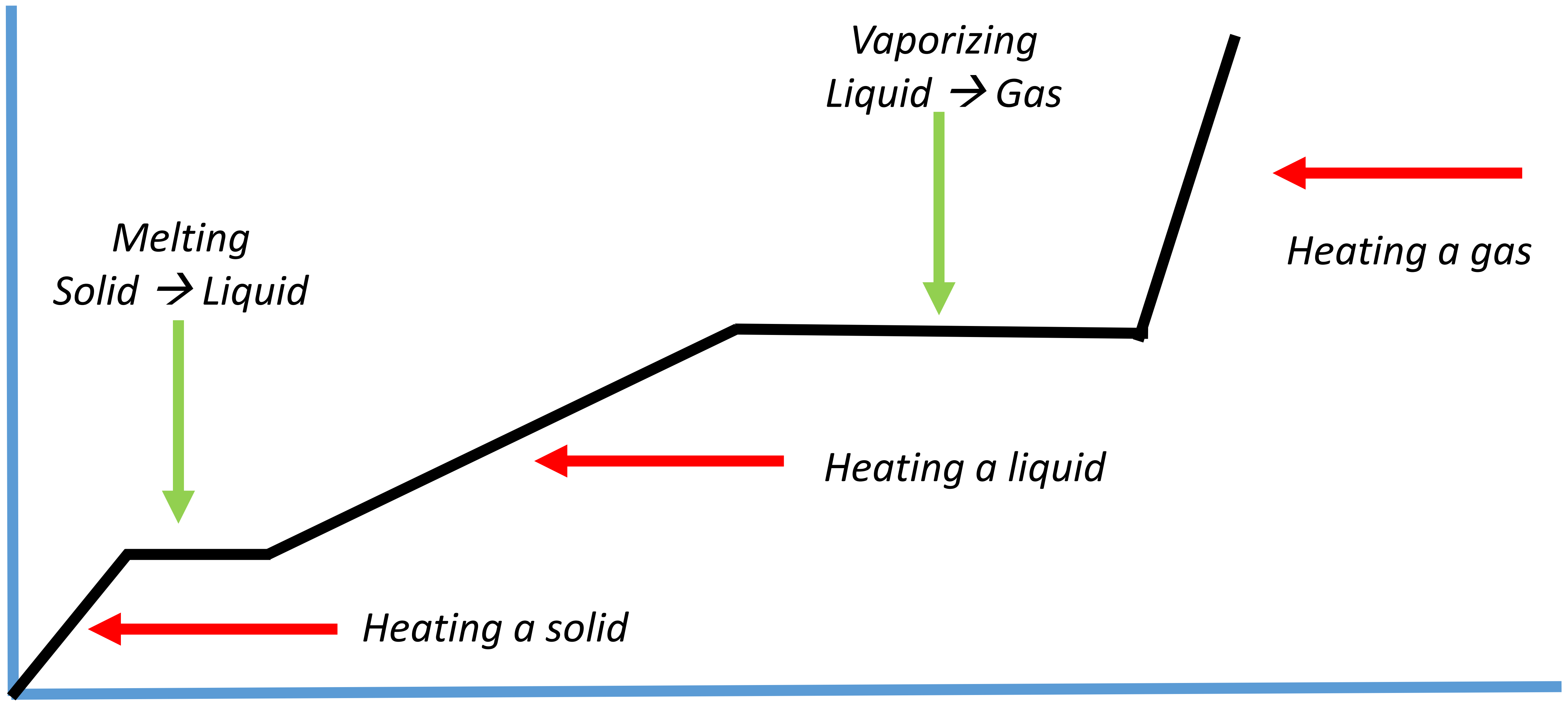
- L_{fusion}
- $L_{vaporization}$
- ***Positive if endothermic process (melting/vaporizing)***
- ***Negative if exothermic process (condensing/freezing)***

Values to Memorize for Water

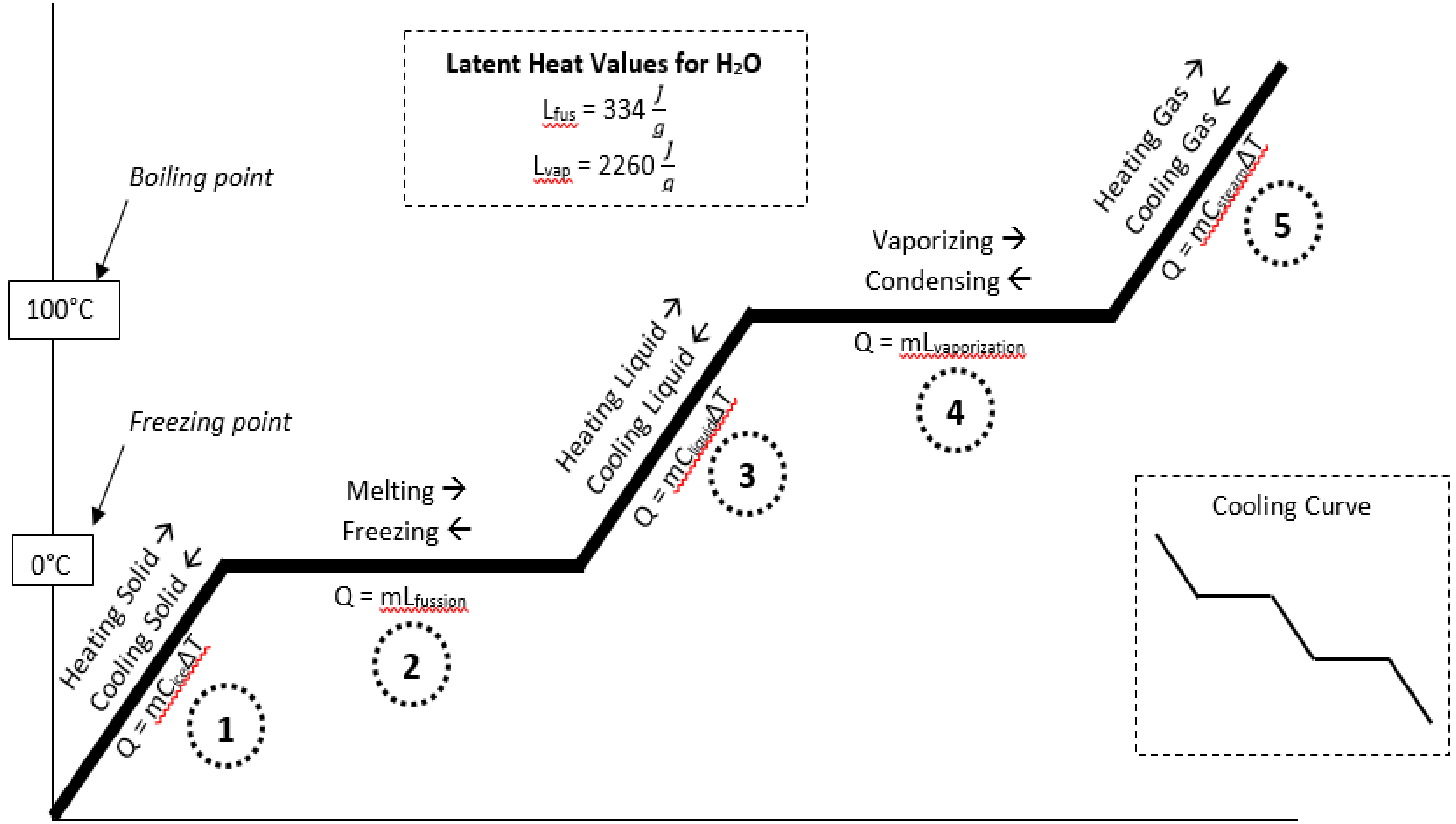
Heating/Cooling		Phase Changes	
C_{ice}	2.09 J/g°C	L_{fus}	+/- 334 J/g
C_{liq}	4.18 J/g°C	L_{vap}	+/- 2260 J/g
C_{steam}	1.87 J/g°C		

L is (+) or (–) depending on direction!

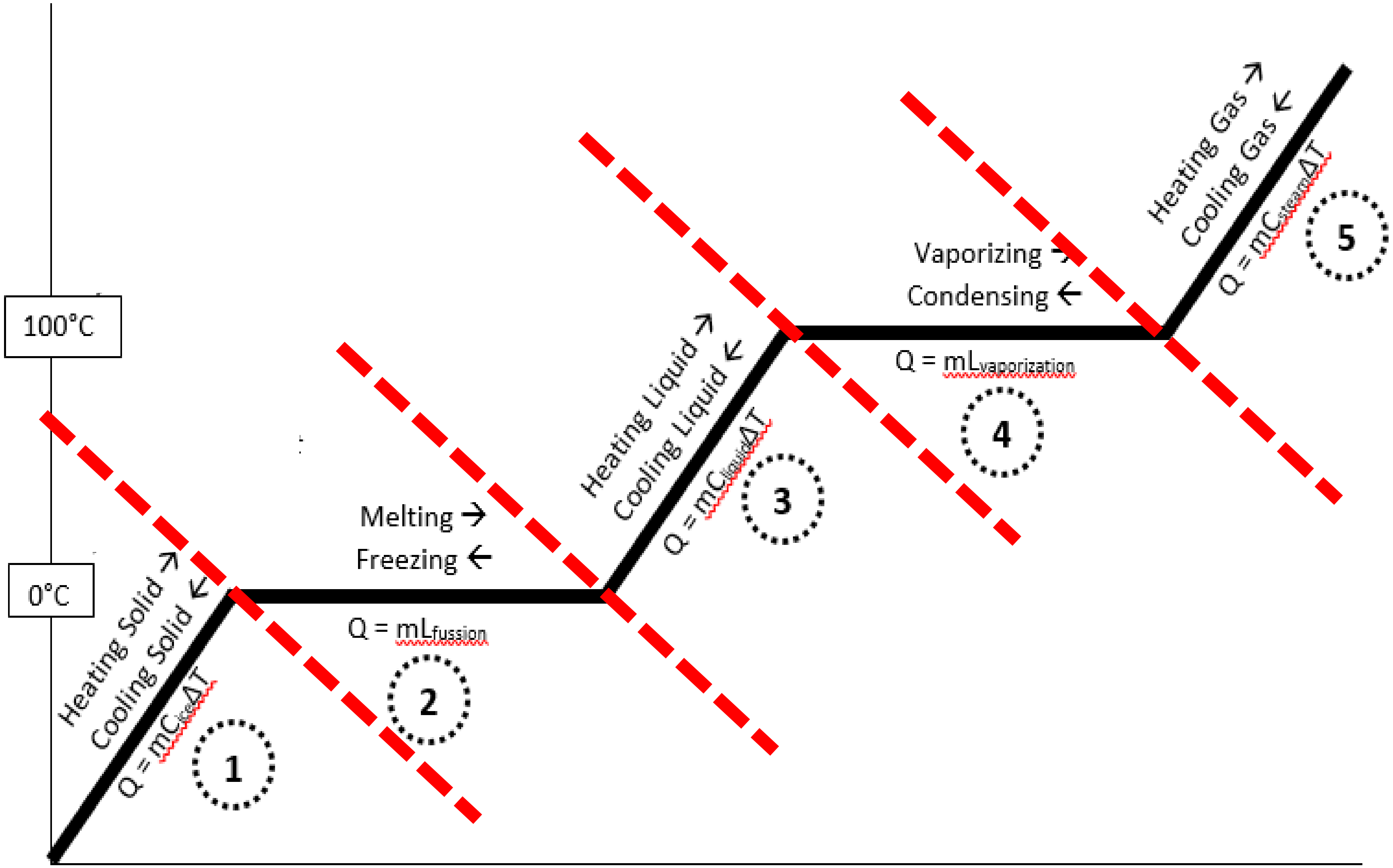
More Realistic Heating Curve of H2O



Completely Labeled Heating Curve

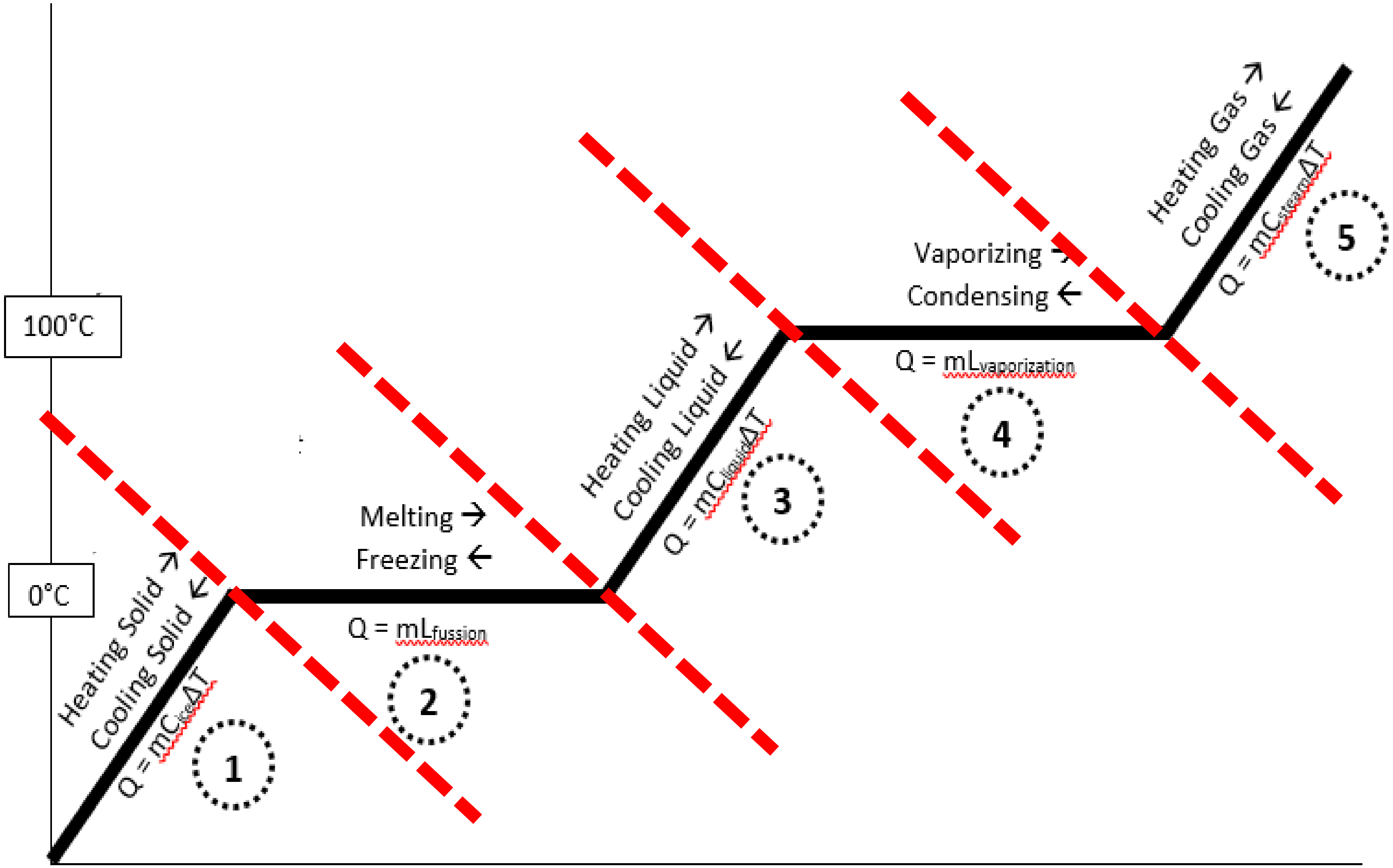


Calculate ONE line segment at a time!!!



Calculate everything separately and then add up your answers. You could have up to five Q values to add up!

Careful with ΔT Values!



Use ONLY the temperature change on the ONE LINE you are working with at a time!

You will see this on our practice problems in a minute…

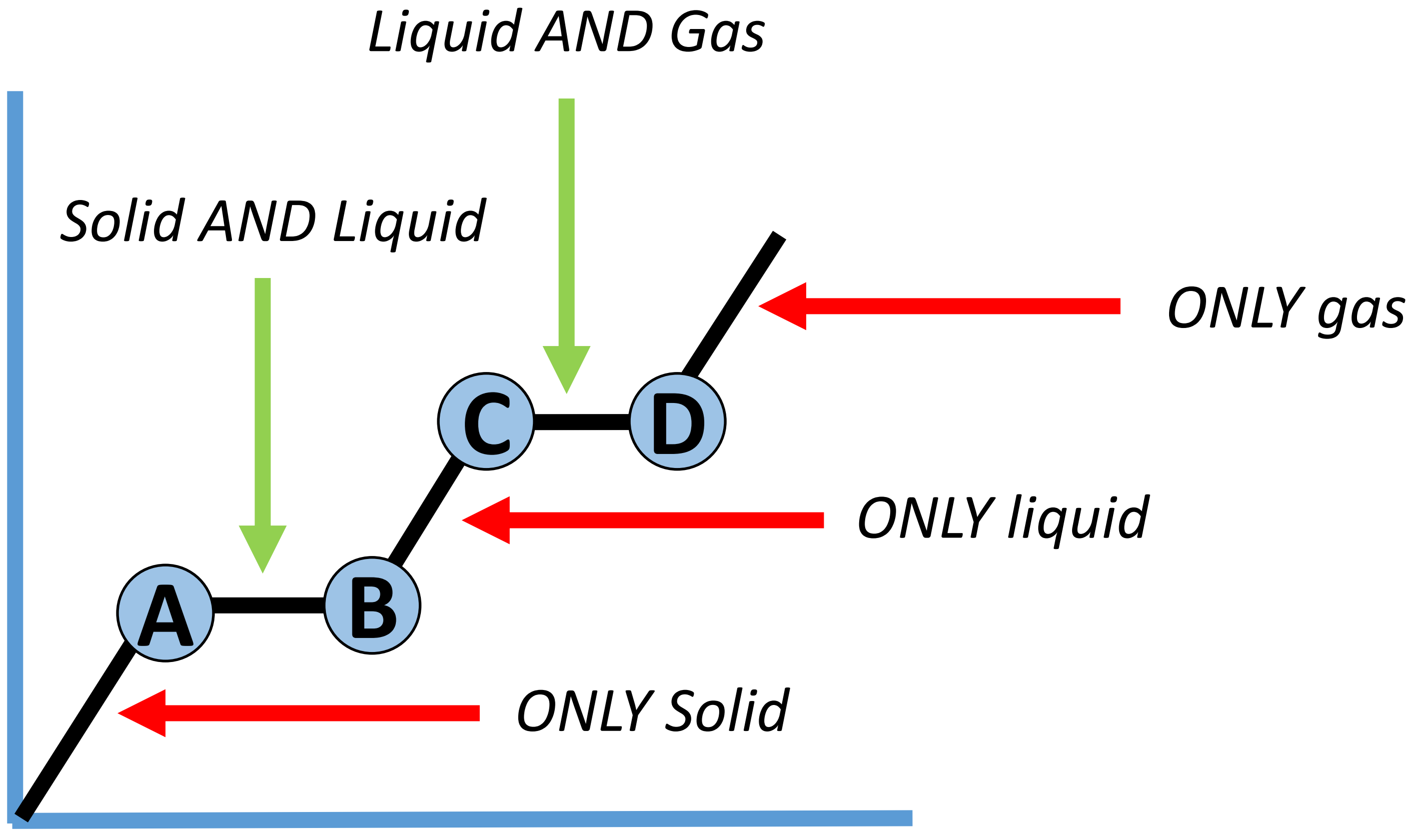
What phases are happening where?

A ONLY Solid at 0°C

B ONLY Liquid at 0°C

C ONLY Liquid at 100°C

D ONLY Gas at 100°C



Practice Problems

- Glue the questions in your notebook
- Show your work the way I do!
- Annotate the practice problems with comments, tips, warnings, explanations, etc! These are NOTES not just practice problems!

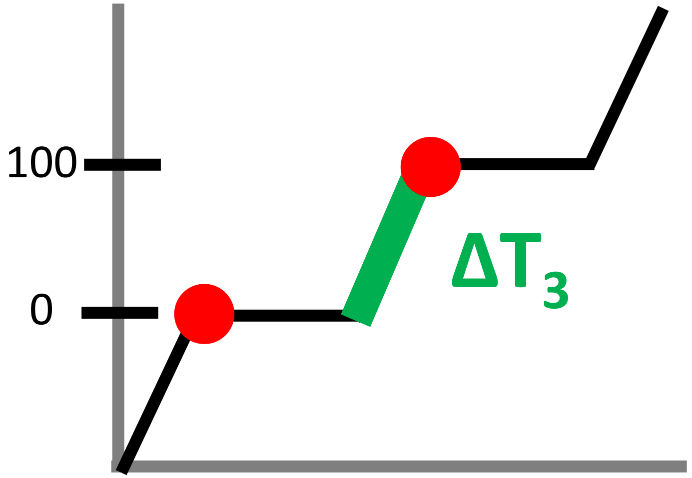
Practice Problems

1. **What is the energy needed to melt 326 grams of ice and heat it to 100°C?**
2. **Determine the energy required to convert 21.1 grams of ice at -6°C to steam at 100°C**
3. **What is the heat transfer involved when you convert 51 grams of water 0°C to ice at -20.3°C?**
4. **What is the energy absorbed when you melt 75 grams of ice at -5°C to water at 90°C?**

1. What is the energy needed to melt 326 grams of ice and heat it to 100°C?

2 Melt ice

3 Heat liquid



Q_2 = mL = (326g)(334 J/g) = *108884 J*

Q_3 = mCΔT = (326g)(4.18J/gC) (100° - 0°) = *136268 J*

Q_T = Q_2 + Q_3

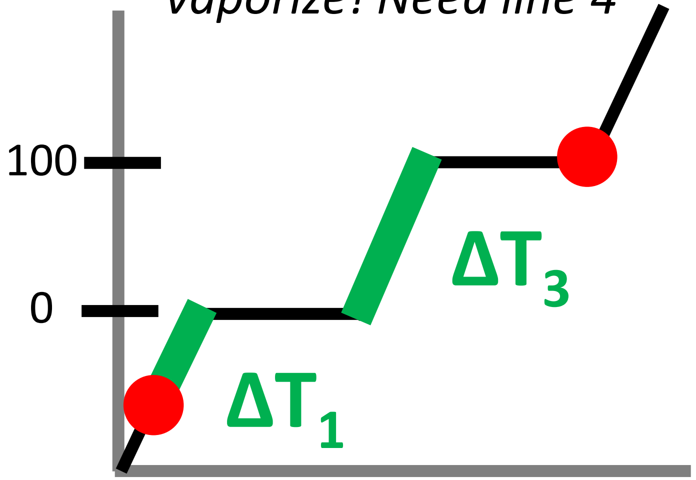
$\boxed{= \textit{245152 J}}$

You could put it in kJ but we often don't bother

2. Determine the energy required to convert 21.1 grams of ice at -6°C to steam at 100°C

1. Heat ice
2. Melt ice
3. Heat liquid
4. Vaporize

Steam @ 100, have to vaporize! Need line 4



Double Negative! Be Careful!

$Q_1 = mC\Delta T = (21.1g)(2.09_{J/gC})(0° - -6°) =$ ***264.59 J***

$Q_2 = mL = (21.1g)(334\ J/g) =$ ***7047.4 J***

$Q_3 = mC\Delta T = (21.1g)(4.18_{J/gC})(100° - 0°) =$ ***8819.8 J***

$Q_4 = mL = (21.1g)(2260\ J/g) =$ ***47686 J***

$Q_T = Q_1 + Q_2 + Q_3 + Q_4$

$\boxed{= 63817.79\ J}$

3. What is the heat transfer involved when you convert 51 grams of water 0°C to ice at -20.3°C?

2 **Freezing**

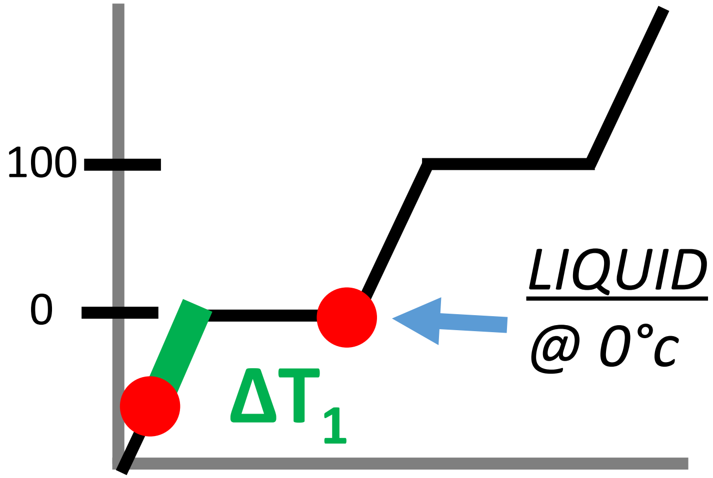
1 **Cooling ice**

Going backwards!

L will be negative!

ΔT will be negative

Q will be negative!



$$Q_2 = mL = (51g)(-334\ J/g) = -17034\ J$$

$$Q_1 = mC\Delta T = (51g)(2.09\ J/gC)(-20.3° - 0°) = -2163.78\ J$$

$$Q_T = Q_2 + Q_1$$

$$\boxed{= -19197.78\ J}$$

Negative because energy was RELEASED!

Cooling down is EXOTHERMIC!

Yes, that seems strange to us but it is true!

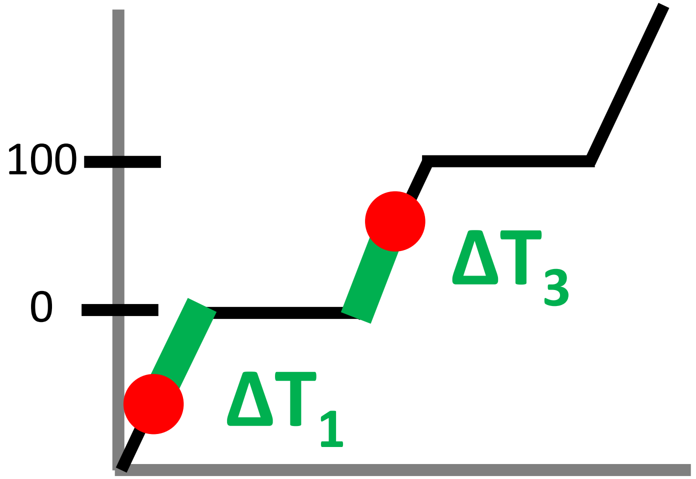
4. What is the energy absorbed when you melt 75 grams of ice at -5°C to water at 90°C?

① **Heat ice**

② **Melt ice**

③ **Heat liquid**

You aren't "finishing" line 3! Stop early! Careful with you ΔT !



Double Negative! Be Careful!

$Q_1 = mC\Delta T = (75g)(2.09_{J/gC})(0° - {-5°}) =$ ***783.75 J***

$Q_2 = mL = (75g)(334\ J/g) =$ ***25050 J***

$Q_3 = mC\Delta T = (75g)(4.18_{J/gC})(90° - 0°) =$ ***28215 J***

CAREFUL!

You are only going to 90°C !

You are stopping early!

Tfinal = 90°C

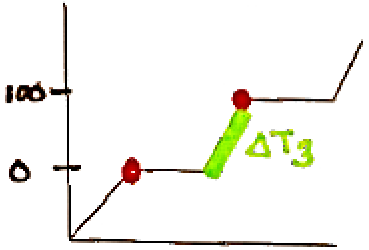
$Q_T = Q_1 + Q_2 + Q_3$

$\boxed{= 54048.75\ J}$

YouTube Link to Presentation

- https://youtu.be/g2srRytHiX0

1. What is the energy needed to melt 326 grams of ice and heat it to 100°C?



② melt ice
③ heat liq.

$$Q_2 = mL = (326g)(334\ J/g) = 108884\ J$$

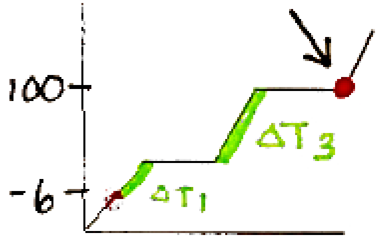
$$Q_3 = mC\Delta T = (326g)(4.18\ J/g°C)(100° - 0°) = 136268\ J$$

$$Q_T = Q_2 + Q_3$$

$$= \boxed{245152\ J}$$

2. Determine the energy required to convert 21.1 grams of ice at -6°C to steam at 100°C

Steam@ 100°! Have to vaporize



① heat ice
② melt ice
③ heat liQ.
④ vaporize

$$Q_1 = mC\Delta T = (21.1g)(2.09\ J/g°C)(0° - -6°) = 264.59\ J$$

double negative! be careful!

$$Q_2 = mL = (21.1g)(334\ J/g) = 7047.4\ J$$

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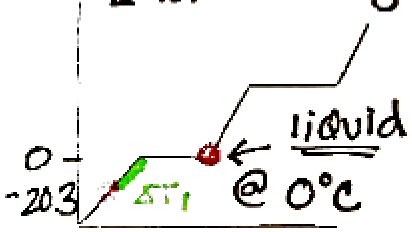
$$Q_T = Q_1 + Q_2 + Q_3 + Q_4$$

$$= \boxed{63817.79\ J}$$

3. What is the heat transfer involved when you convert 51 grams of water 0°C to ice at -20.3°C?

going backwards! L will be negative!



② freezing
① cooling ice

$Q_2 = mL = (51g)(-334\ J/g) = -17034\ J$

$Q_1 = mC\Delta T = (51g)(2.09\ J/g°C)(-20.3° - 0°) = -2163.78 J$

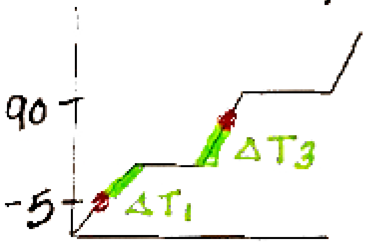
$Q_T = Q_2 + Q_1$

$= \boxed{-19197.78\ J}$

negative b/c energy is released!

4. What is the energy absorbed when you melt 75 grams of ice at -5°C to water at 90°C?

you aren't "finishing" line 3! Stop early! careful w/ ΔT



① heat ice
② melt ice
③ heat LiQ.

$Q_1 = mC\Delta T = (75g)(2.09\ J/g°C)(0° - -5°) = 783.75\ J$ double negative!

$Q_2 = mL = (75g)(334\ J/g) = 25050\ J$

$Q_3 = mC\Delta T = (75g)(4.18\ J/g°C)(90° - 0°) = 28215\ J$

only going to 90°C!

$Q_T = Q_1 + Q_2 + Q_3$

$= \boxed{54048.75\ J}$